Achieving Ubiquity through Hardware Virtualization

Mahadev Satyanarayanan

School of Computer Science

Carnegie Mellon University

Essence of Weiser's Vision

Creation of computing environments that

1. ***"are saturated with computing and communication"***
2. ***"yet gracefully integrated with human activities"***

We have done a great job on #1

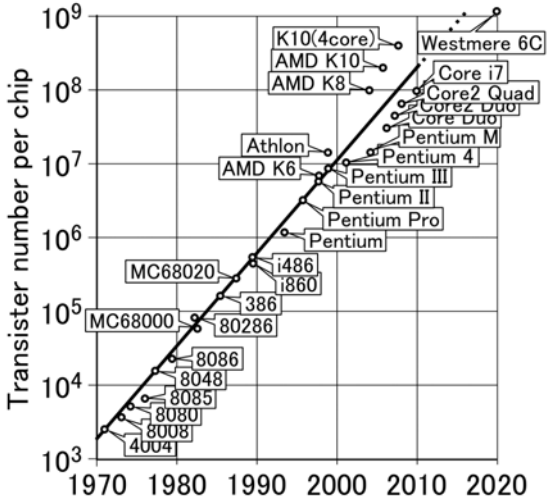
We have hardly scratched the surface on #2

- **at best, we have created potentially useful components**
- **e.g., context awareness toolkits, smart space toolkits, sensing and activity inferencing toolkits, OS extensions for application-aware adaptation and transparency to disconnections and weak connectivity, …**
- **but *"gracefully integrated" . . . ?***

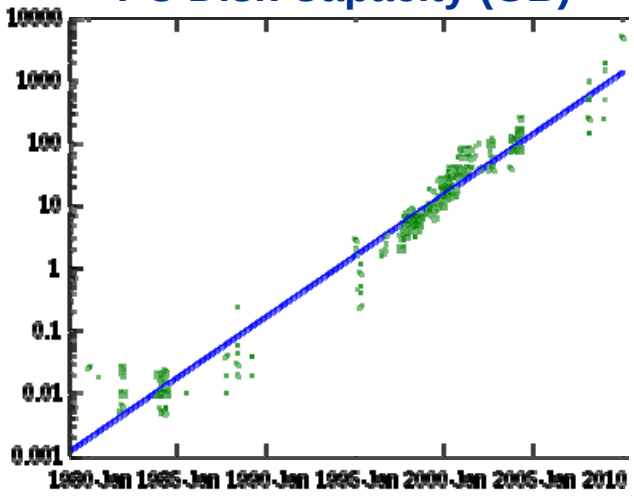
Moore's Law Reigns Supreme

(Figure credits: various Wikipedia sources)

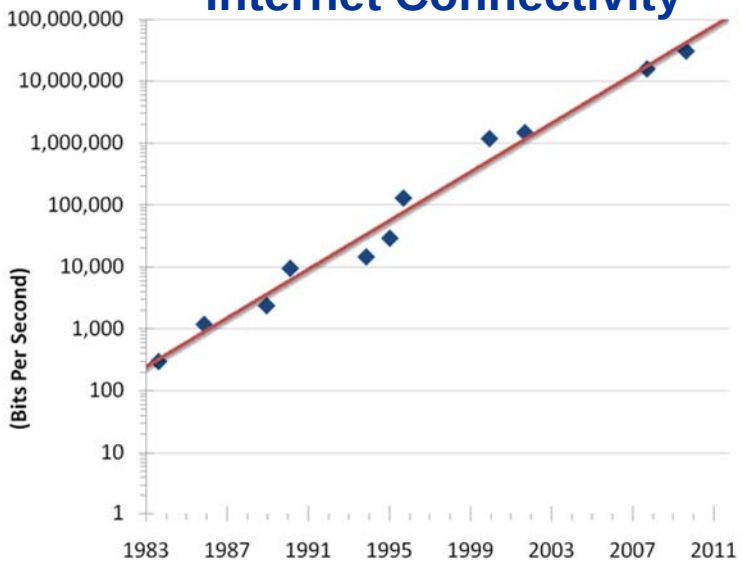
Processors

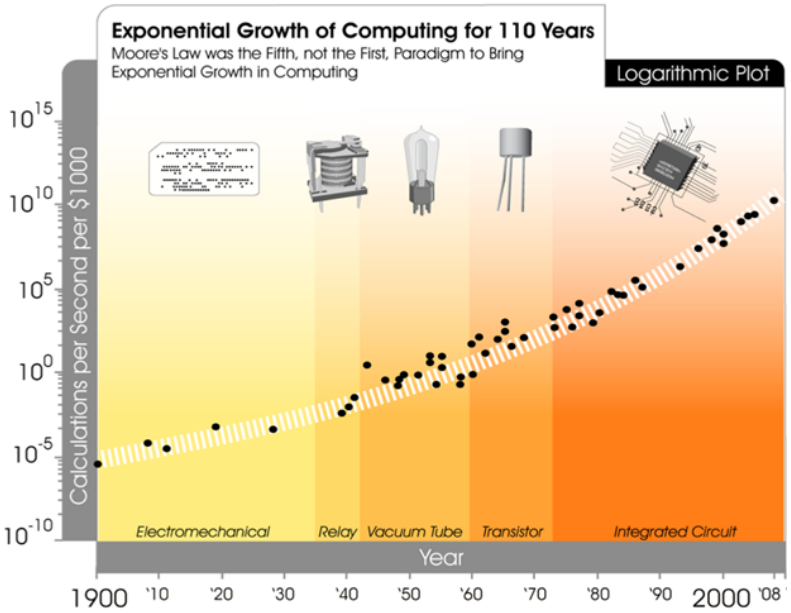


PC Disk Capacity (GB)



Internet Connectivity





Glaring Exception

"...in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. **What information consumes is rather obvious: it consumes the attention of its recipients.** Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it"

Simon, H., 1971
"Designing Organizations for an Information-Rich World"

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Weiser, M., 1991
"The Computer for the 21st Century"

Integration, Deployment & Scaling - I

Wide interfaces → external complexity → *brittle abstractions*

Hard to deploy, hard to sustain, hard to scale

Cautionary lesson of *process migration*

- **1983 to 2011, PhD theses roughly every 5 years**
- **not supported by any production OS today (open or closed)**
- **great idea whose time has never come!**

Will our pervasive computing abstractions suffer the same fate?

Integration, Deployment & Scaling - II

Contrast the wild real-world success of *VM migration*

- **VMs are a key enabler of cloud computing**
- **widely used production-quality implementations**

Can we harness hardware virtualization in pervasive computing?

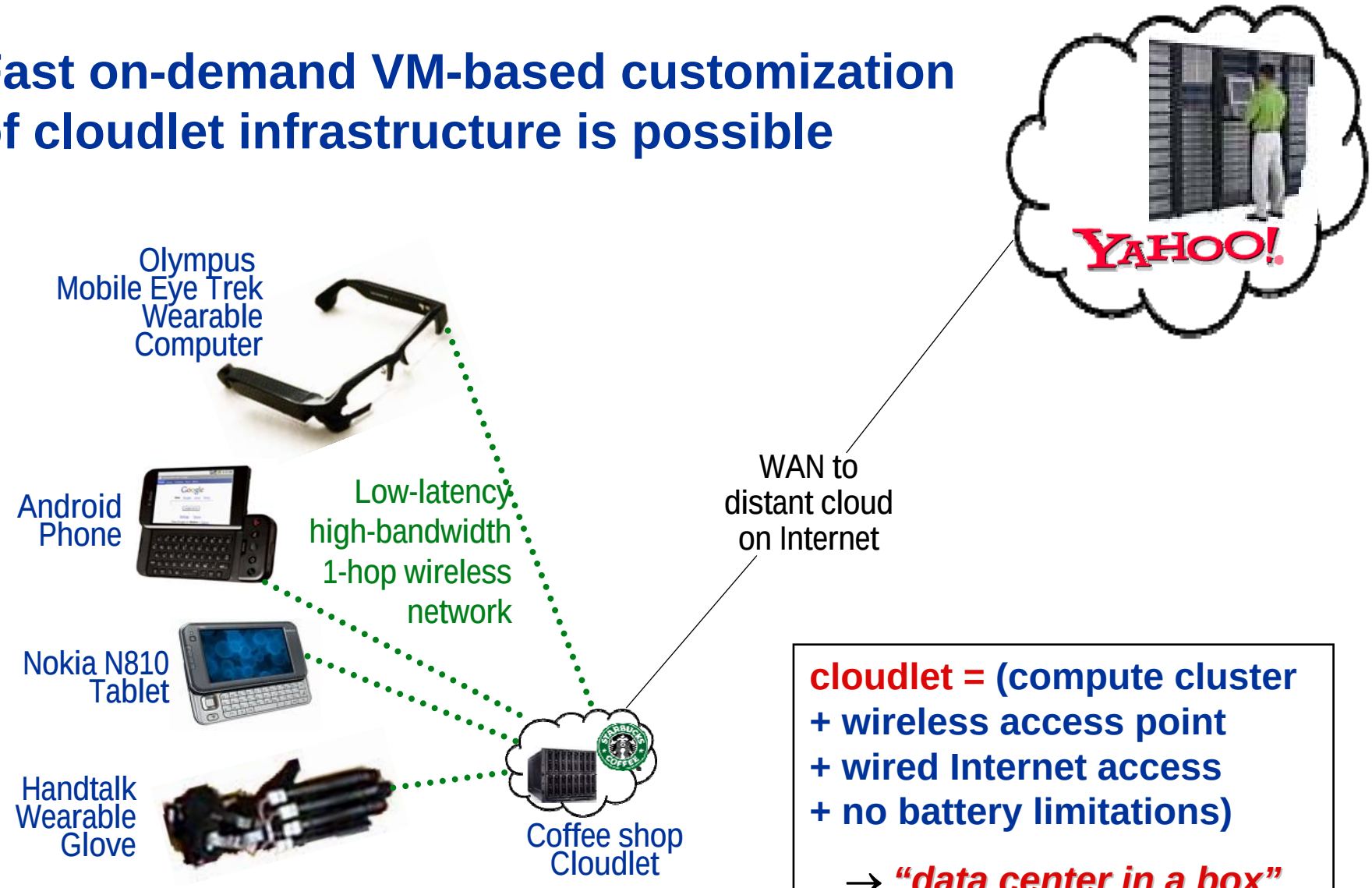
- **VMs transform external complexity into internal complexity**
- **replace highly mutable interfaces with a very stable one**
- **software virtualization (e.g. JVM) just doesn't cut it**

Two example use cases of VMs in mobile and pervasive computing

- **use in *cloudlets* for cyber foraging**
- **use in *transient PCs* for legacy support**

Cloudlet = Small Cloud Nearby

Fast on-demand VM-based customization of cloudlet infrastructure is possible



cloudlet = (compute cluster
+ wireless access point
+ wired Internet access
+ no battery limitations)

→ ***"data center in a box"***

Transient PCs

Our current PC world is a legacy for the new pervasive computing world

Extended period of co-existence likely

VM-based transient PCs are a key technology for this coexistence